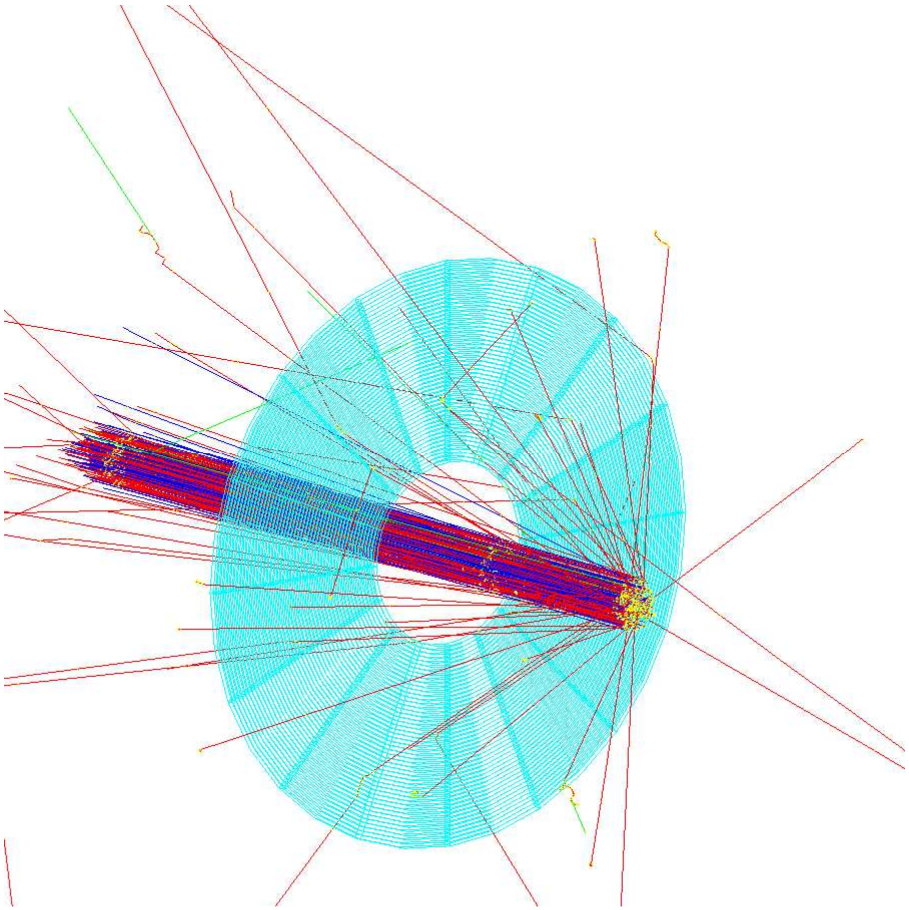
Triplet polarimeter study



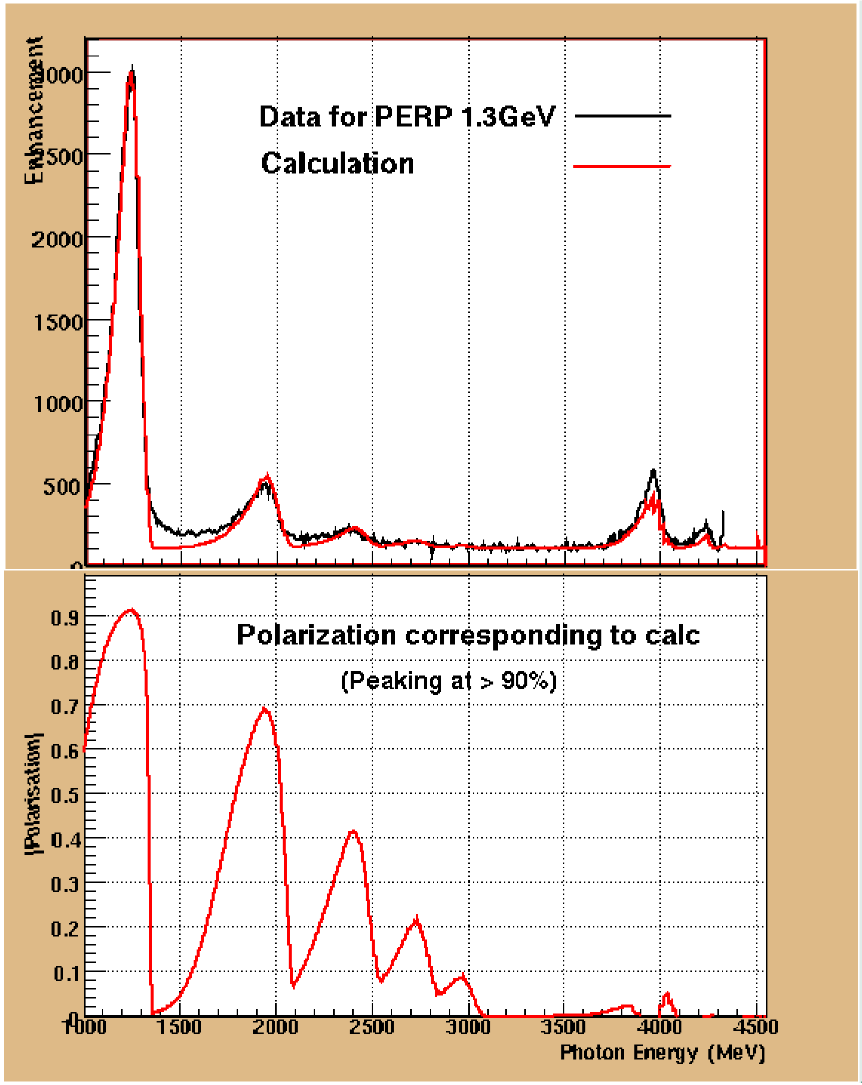
Michael Dugger*
Arizona State University

*Work at ASU is supported by the U.S. National Science Foundation

Outline

- Results of g8b consistency study of the polarization determined by CBSA
- Brief overview of triplet production
- Potential detector
- Event generator
- δ-rays
- Results of simulation
- Stray magnetic fields
- Mainz test

Run period g8b (June 20- Sept 1, 2005)



- Coherent bremsstrahlung in 50 μ diamond
- Two linear polarization states (vertical & horizontal)
- Incident electron energy of 4.55 GeV
- Analytical QED coherent bremsstrahlung calculation fit to actual spectrum:CBSA (Livingston/Glasgow)
- ⊥ 1.3 GeV edge shown

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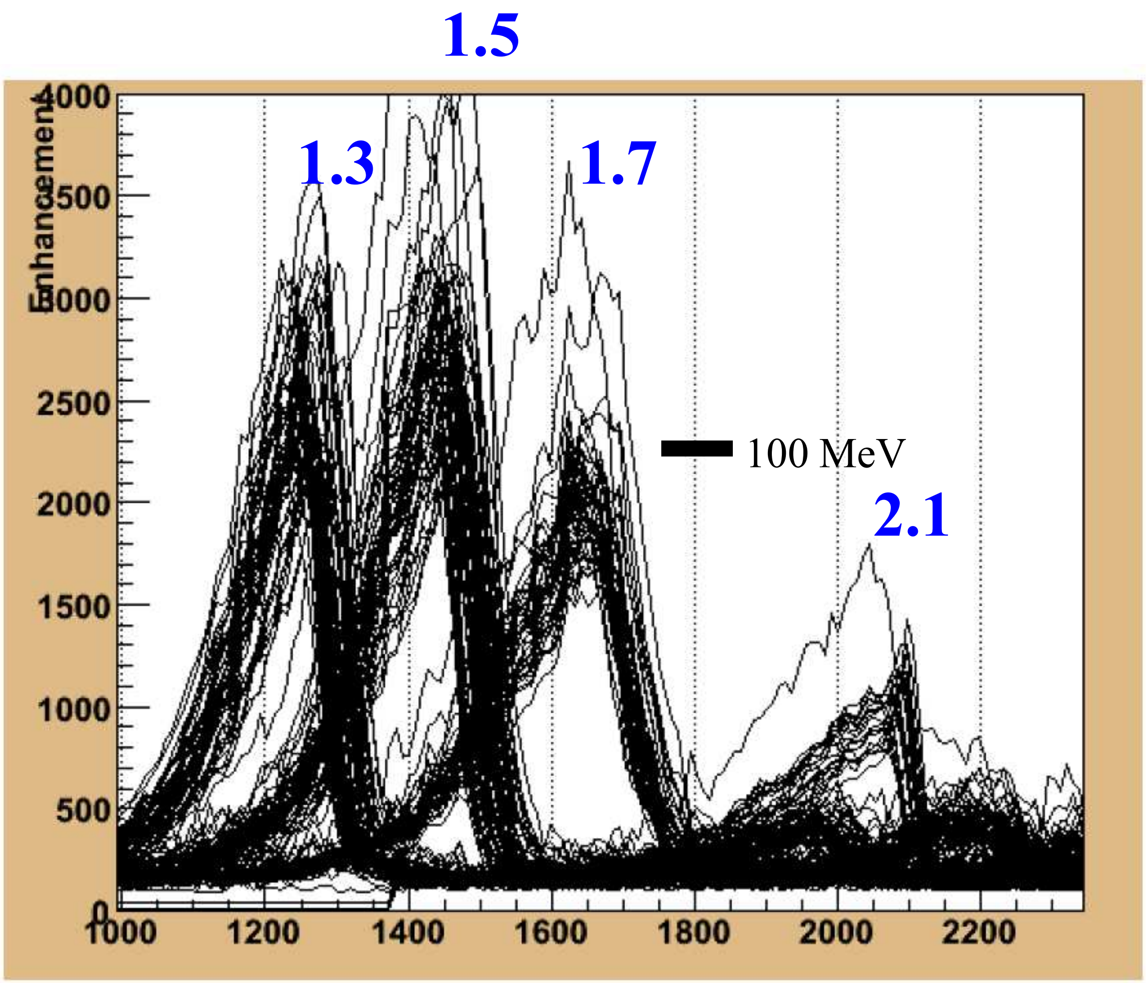
Statistics for g8b

Coherent Edge	Billions of events
• Non-polarized (amorphous)	2.3
• 1.3 GeV	1.4
• 1.5 GeV	2.6
• 1.7 GeV	2.2
• 1.9 GeV	1.2
• 2.1 GeV	0.9

Coherent edge is unstable

- Auto-flip data not shown
- All 1.9 GeV is auto-flip
- Coherent edge moves ~ 50 MeV or more



Results from the consistency study of the g8b polarization

Type of comparison		Distance of consistency from unity (%) Unmodified polarization	Modified polarization
1.3 - 1.5 overlap region	PARA	5.9(7)	1.4(8)
	PERP	5.1(8)	0.6(9)
1.5 - 1.7 overlap region	PARA	5.0(9)	1.4(9)
	PERP	7(1)	1(1)
1.7(auto) - 1.9 overlap region	PARA	9(3)	4(3)
	PERP	4(2)	1(3)
1.7(manual) - 1.9 overlap region	PARA	10(2)	2(2)
	PERP	8(2)	1(2)
1.7 (manual) - 1.7 (auto) overlap region	PARA	1.8(7)	1.2(7)
	PERP	2.9(7)	0.5(7)
1.9 - 2.1 overlap region	**PARA**	**10(1)**	**5(2)**
	PERP	**17(4)**	**8(4)**
1.3 PARA to PERP ratio		1(3)	2.1(3)
1.5 PARA to PERP ratio		3.2(3)	2.7(3)
1.7 manual PARA to PERP ratio		0.6 (5)	0.7(5)
1.7 auto PARA to PERP ratio		0.4(6)	0.4(6)
1.9 PARA to PERP ratio		2.5(8)	0.4(8)
2.1 PARA to PERP ratio		**5(1)**	**17(1)**

- Neglecting the 2.1 GeV data set we can get consistency better than 5%

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Why have a triplet polarimeter?

Having a polarization measurement independent of CBSA would

• Help in determining consistency corrections to CBSA

• Either confirm CBSA or substitute for CBSA if CBSA fails or has a larger systematic uncertainty

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Brief overview of triplet production

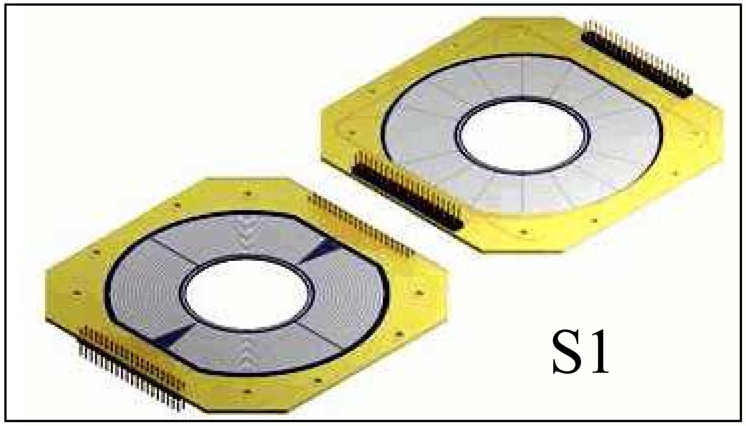
- Pair production **off a nucleon**: γ nucleon $\rightarrow$ nucleon $e^+ e^-$.

- For polarized photons $\sigma = \sigma_0[1 + P\Sigma \cos(2\varphi)]$, where σ_0 is the unpolarized cross section, P is the photon beam polarization and Σ is the beam asymmetry

- Triplet production **off an electron**: $\gamma\, e^- \rightarrow e_R^-\, e^+\, e^-$, where e_R represents the recoil electron

- Any residual momentum in the transverse direction of the $e^- e^+$ pair is compensated for by the slow moving recoil electron. This means that the recoil electron can attain large polar angles shifted about 90 degrees in the azimuthal direction relative to the plane containing the pair.

Potential detector

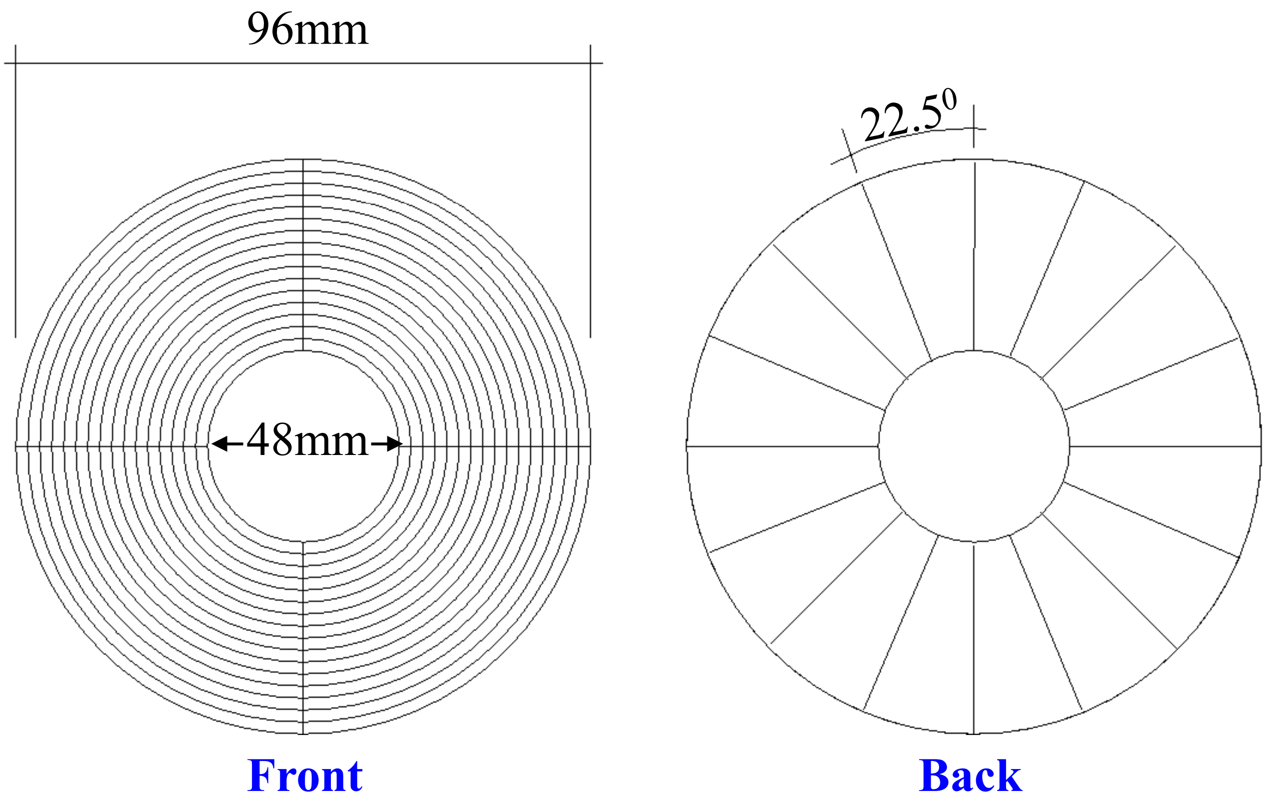


Front:
4 sectors
16 strips/sector

Back:
16 sectors

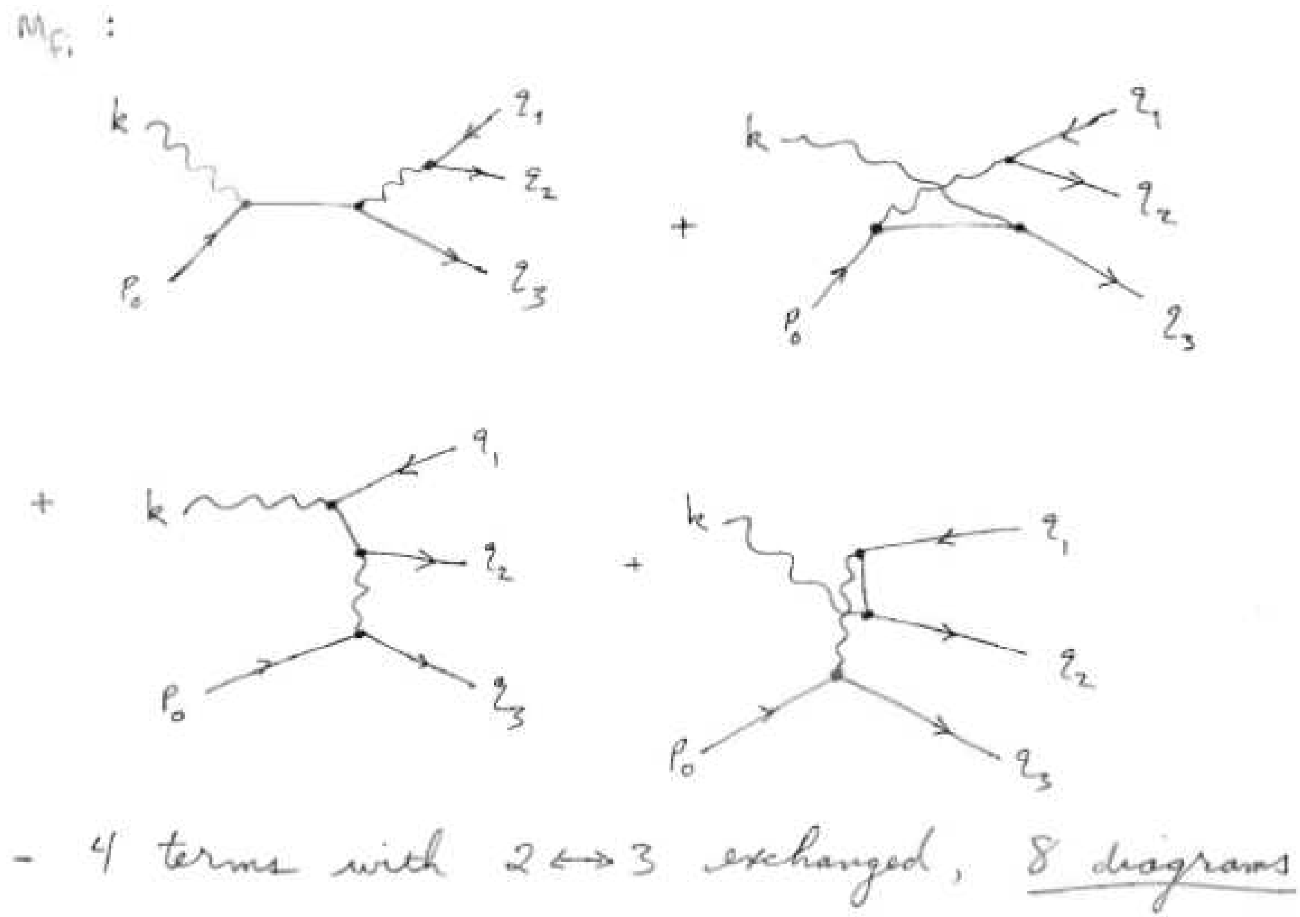
Cost: $7500
(back stock)

Manufacturer:
Micron
Semiconductor



Event generator

• Richard Jones provided an event generator that calculates QED tree level Feynman diagrams:



Triplet asymmetry fits

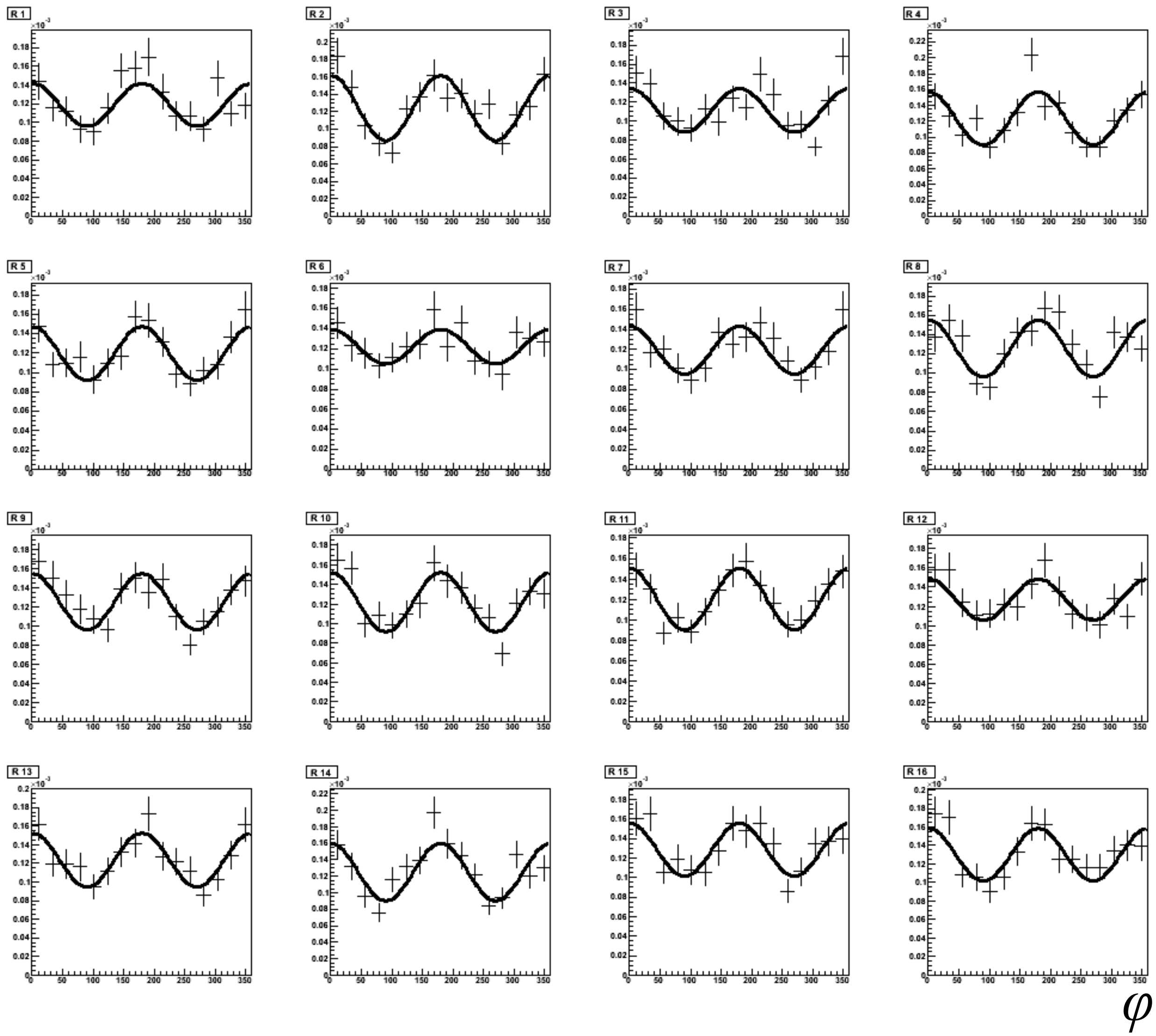
- 10 million generated events using Richard's code

- $E_\gamma = 9.0$ GeV

- $\Delta E_{pair} < 1.5$ GeV

- Fit each ring separately

- Fit function: $A[1 + B\cos(2\varphi)]$



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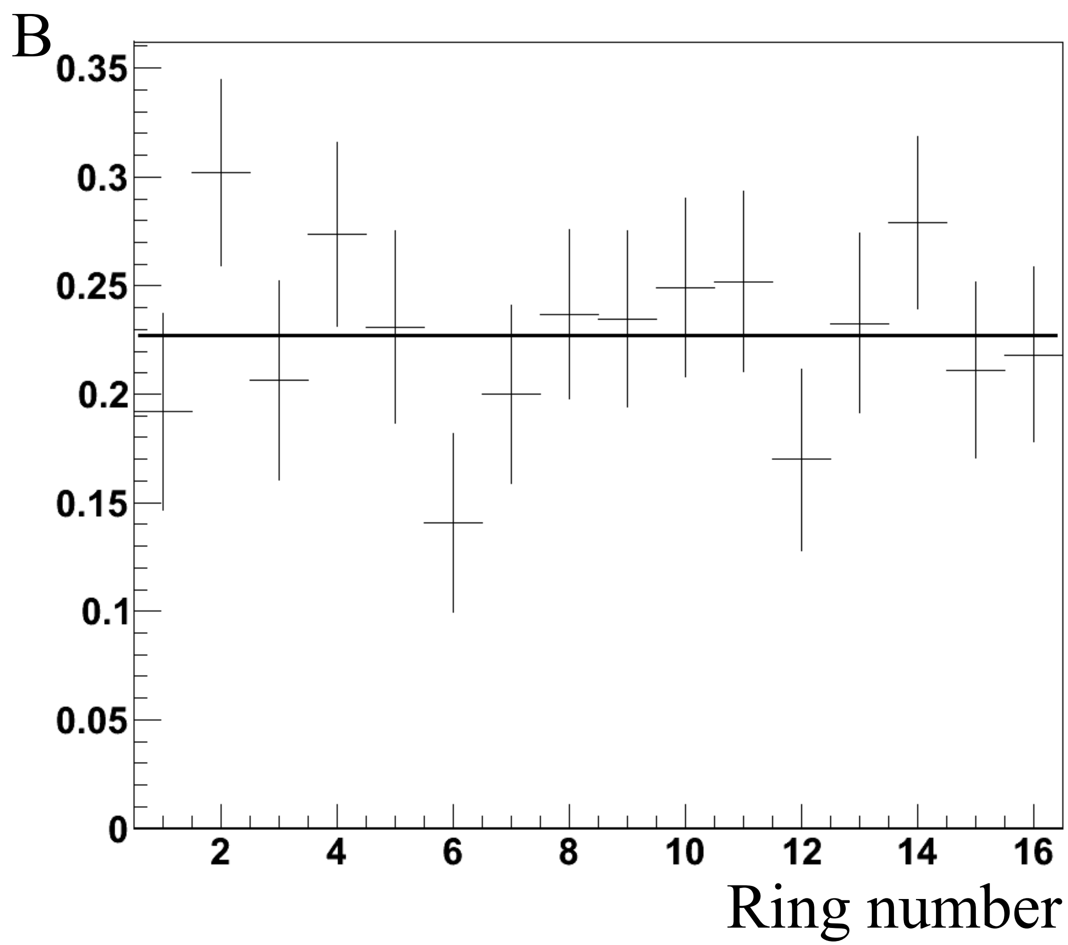
Triplet asymmetry fit results
A[1 + Bcos(2φ)]

• Parameter B from fit

• Results fairly consistent over ring number (inner most ring number = 1)

• Zero order fit:
22.7   0.1



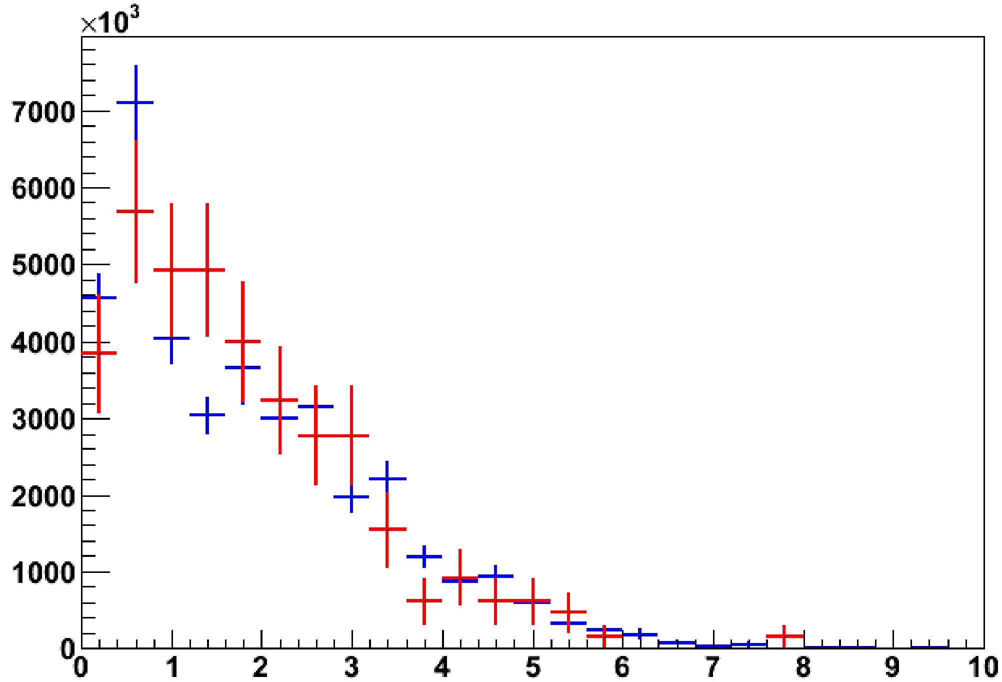
δ-ray comparison with Iwata 1993 simulation

- E_δ is δ-ray kinetic energy after traveling through 1 mm of scintillator using Iwata's polar geometry and scintillator widths

- **BLUE**: Current ASU GEANT4 results

- **RED**: Iwata GEANT3 (scaled to GEANT4 results by ratio of signal integration)

- Shapes of the distributions look similar



E_δ (MeV)

- ASU simulation E_γ = 300 MeV

- Iwata simulation E_γ = 250, 365, 450 MeV

Note: ASU simulation did not wrap scintillators

Results of simulation

NIST cross sections for triplet and pair production off carbon and lithium

σ_{pair}:

0.267 barns/atom @ 0.5 GeV
0.297 barns/atom @ 9.0 GeV

$\sigma_{triplet}$:

0.0479 barns/atom @ 0.5 GeV
0.0575 barns/atom @ 9.0 GeV

carbon

σ_{pair}:

0.0683 barns/atom @ 0.5 GeV
0.0762 barns/atom @ 9.0 GeV

$\sigma_{triplet}$:

0.0245 barns/atom @ 0.5 GeV
0.0304 barns/atom @ 9.0 GeV

lithium
(better triplet to pair ratio but highly reactive and flammable)

NOTE: In previous presentations I misplaced the decimal in the cross sections (for the rate calculations). The rates are now 10 times previous estimates.

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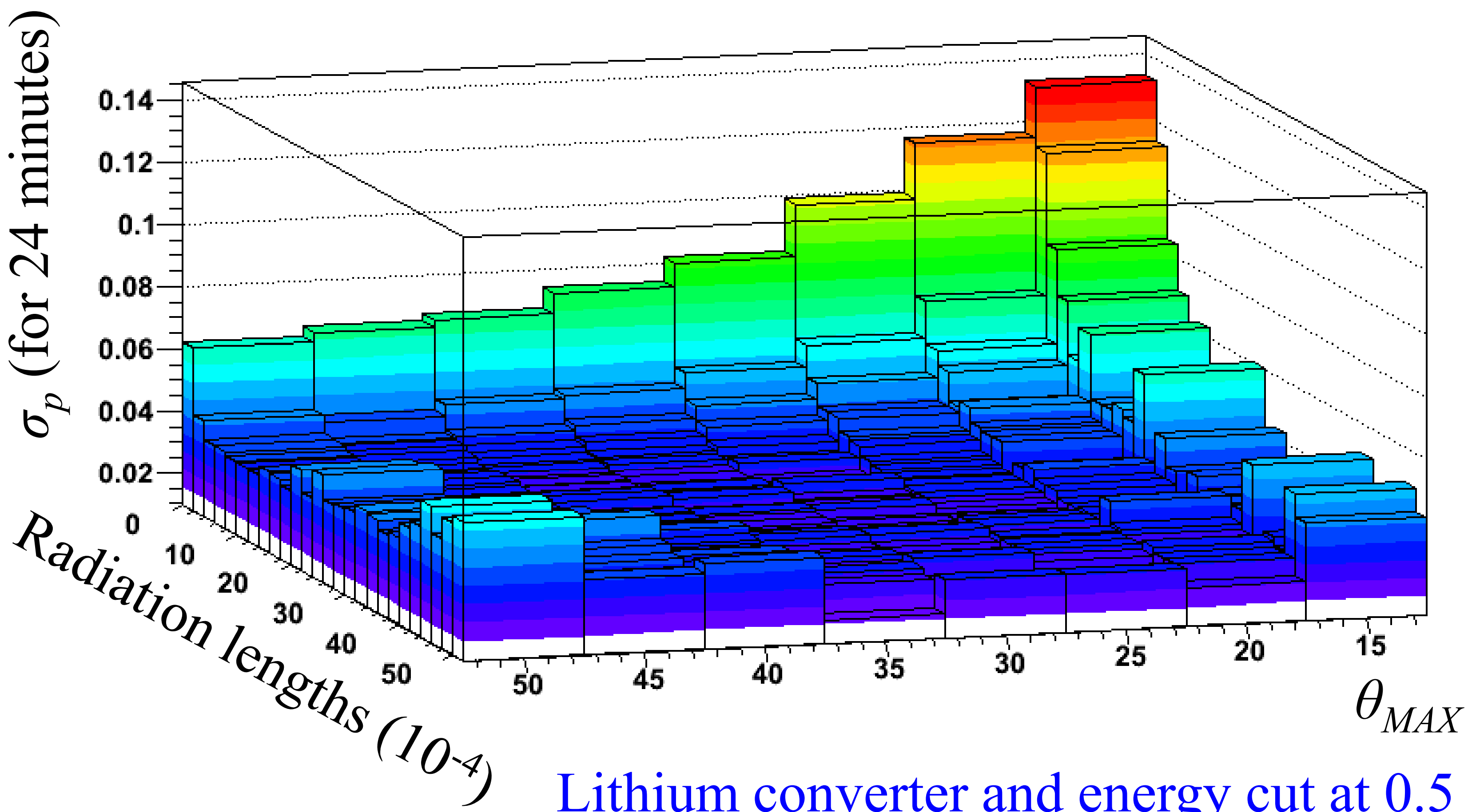
Absolute polarization uncertainty in 24 minutes of running



Lithium converter and energy cut at 0.5 MeV

Assumed $\frac{\sigma_P}{P} = \sqrt{\frac{1}{N}}\sqrt{\frac{2}{\alpha^2 P^2} - 1}$

where N ≡ Rate * 24 minutes,
P ≡ Polarization = 0.4, and
α ≡ analyzing power

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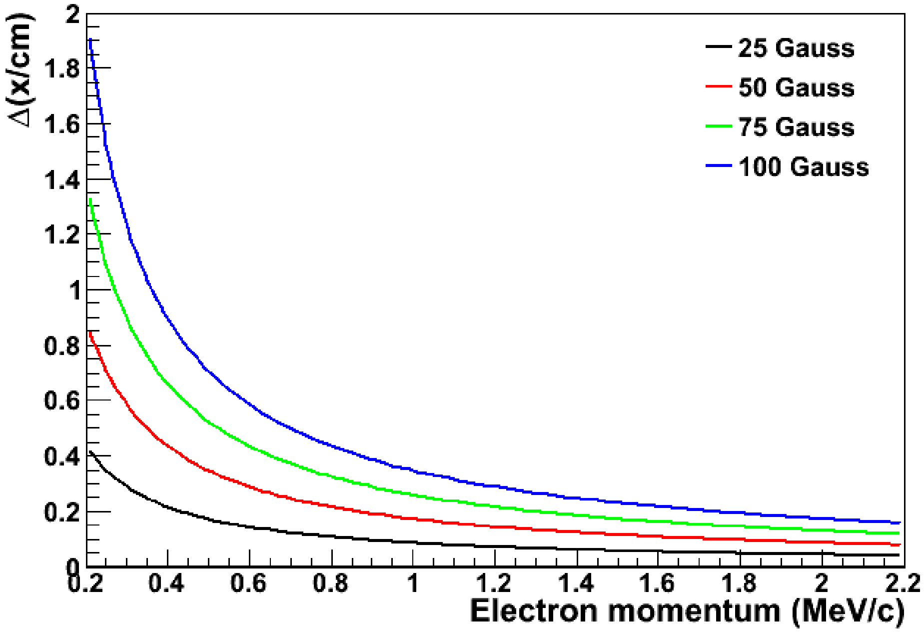
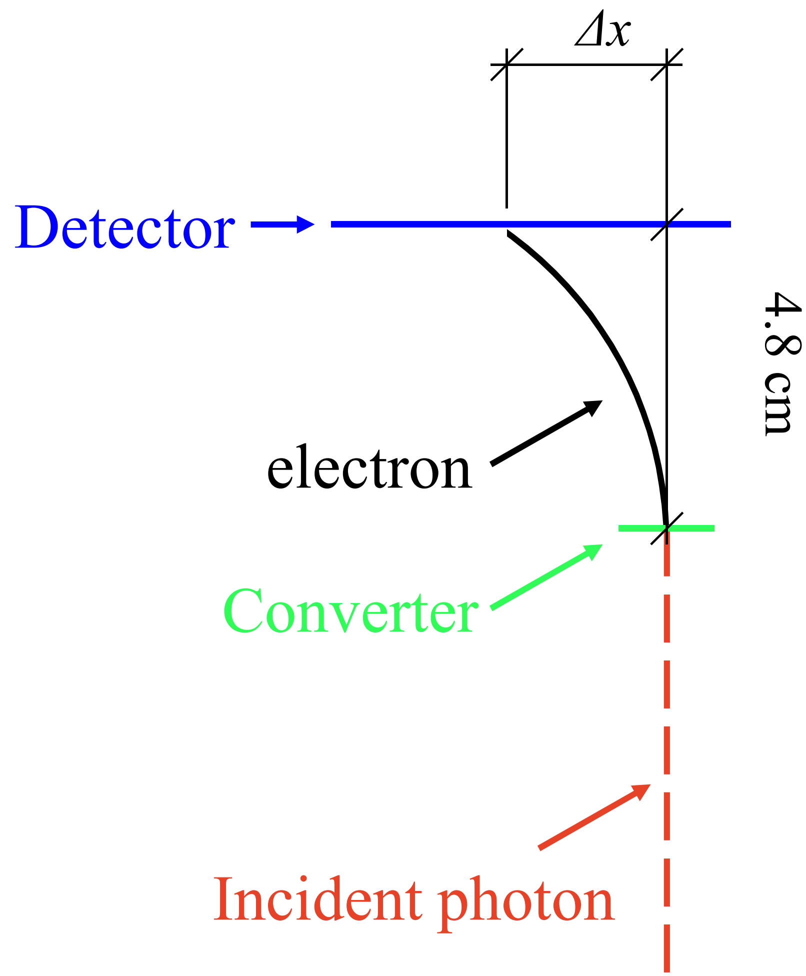
Study of magnetic field on polarimeter

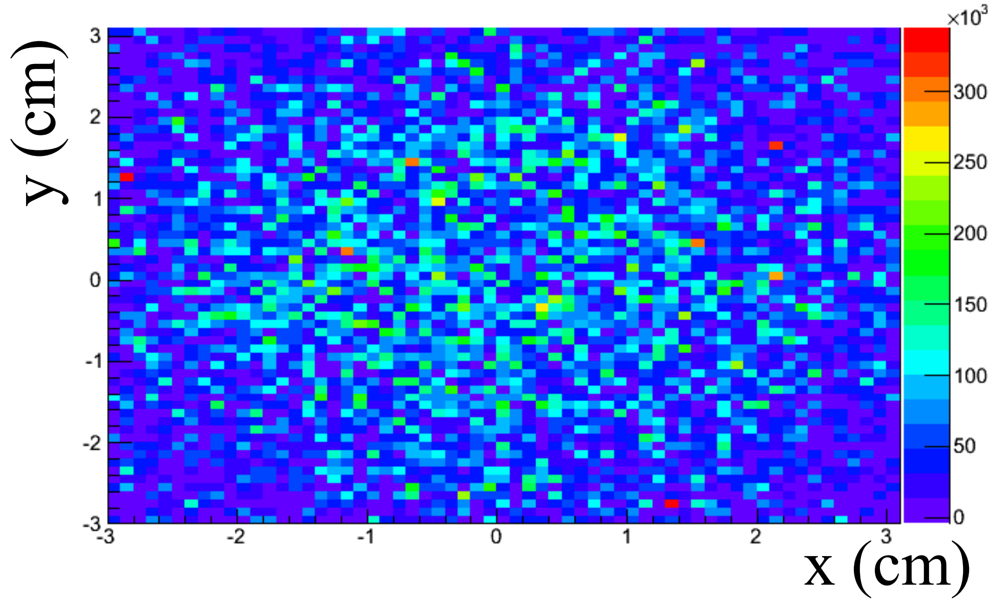
Effect of magnetic field on electron



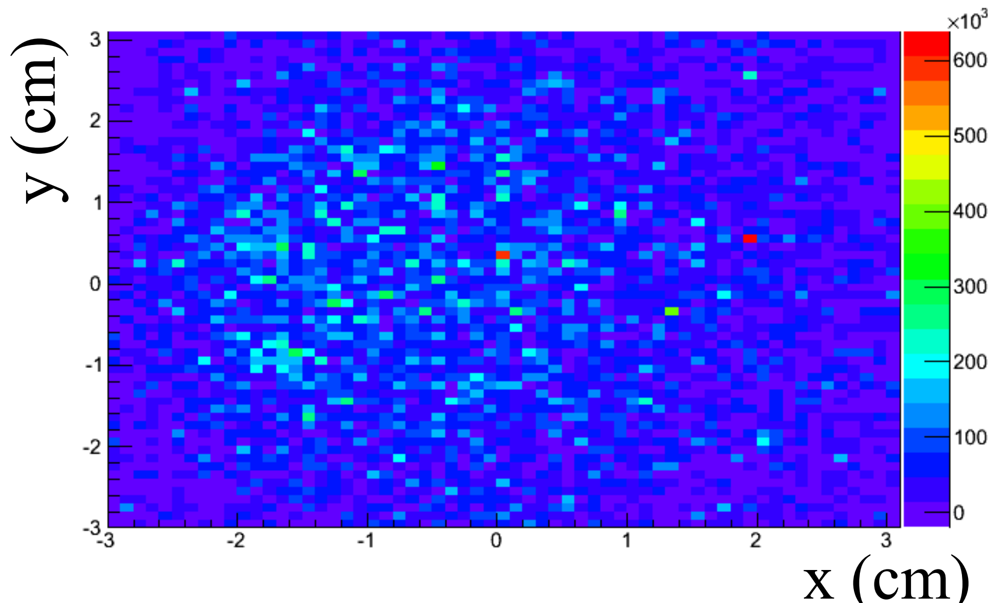


Effect of B-field on δ-rays

No field →

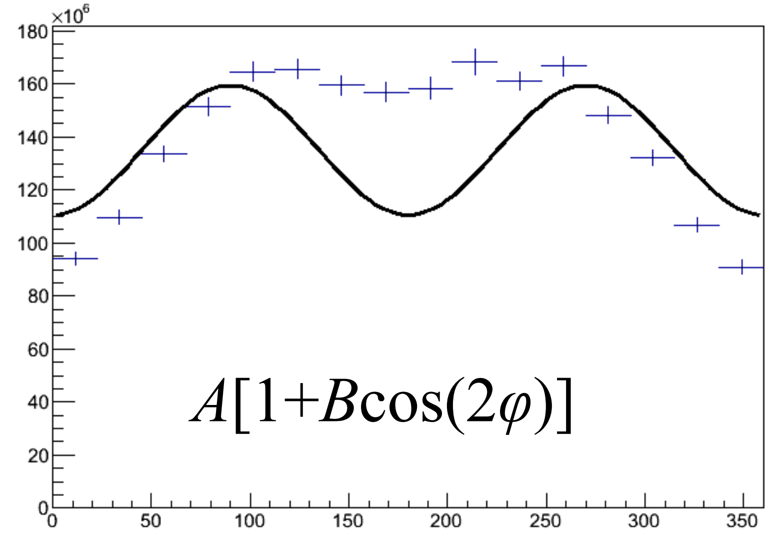


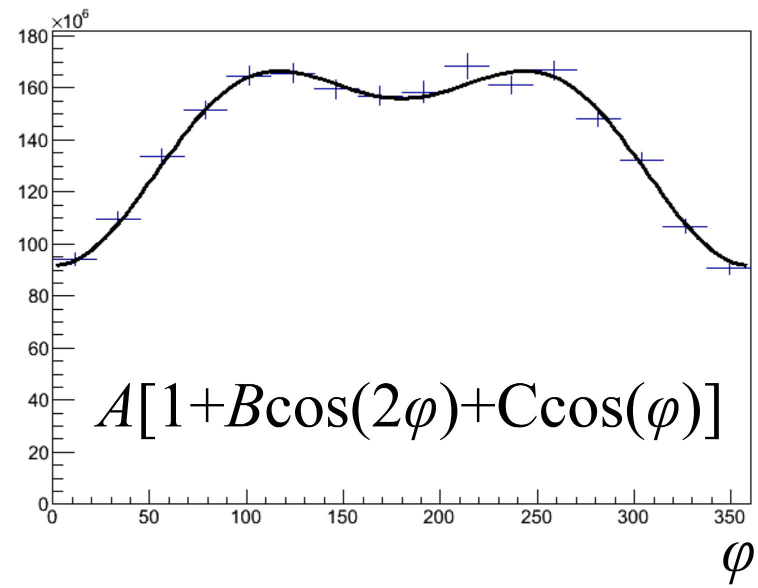
350 gauss field →



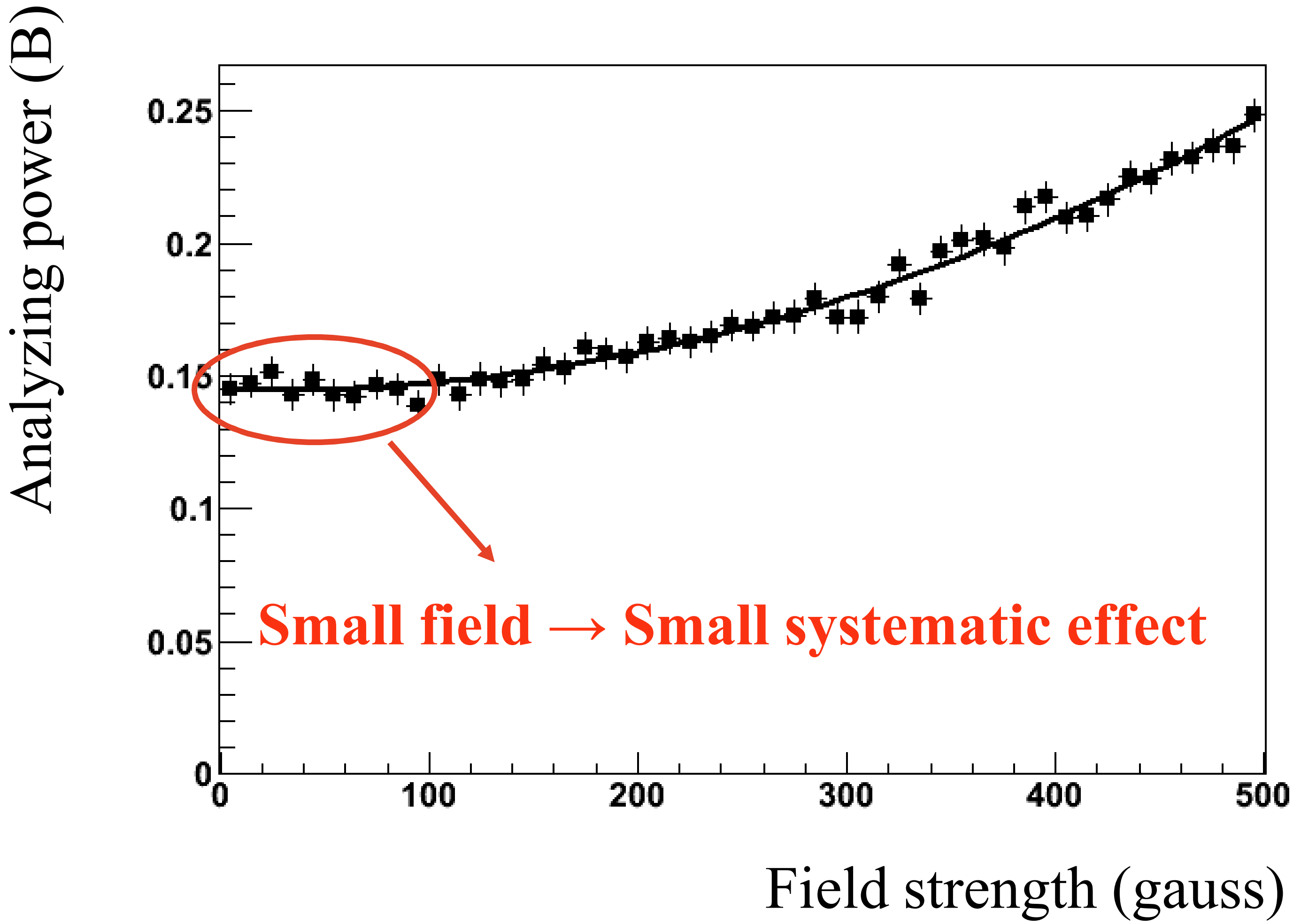
Azimuthal distribution with applied B-field

• 350 gauss field applied





Analyzing power vs. B-field



Potential material for magnetic shielding

High Permeability (AD-MU-80)
Initial Permeability at 40 gauss: 55,000 - 75,000
Permeability at 100 - 200 gauss: 70,000 - 100,000

- If we wrap the polarimeter with a couple layers of AD-MU-80 we should be able to get the stray fields inside to be below a Gauss

The cost is likely not high. They advertise an engineering kit:

- Four (4) feet of AD-MU-80 .004 in. Thick x 15 in. Wide
- Four (4) feet of AD-MU-80 .006 in. Thick x 4 in. Wide
- Four (4) feet of AD-MU-00 .004 in. Thick x 15 in. Wide

Cost: $183.50

Testing a device at Mainz

- The next few slides are from Ken Livingston’s talk at the GlueX upgrade meeting about testing a triplet polarimeter at Mainz ☺

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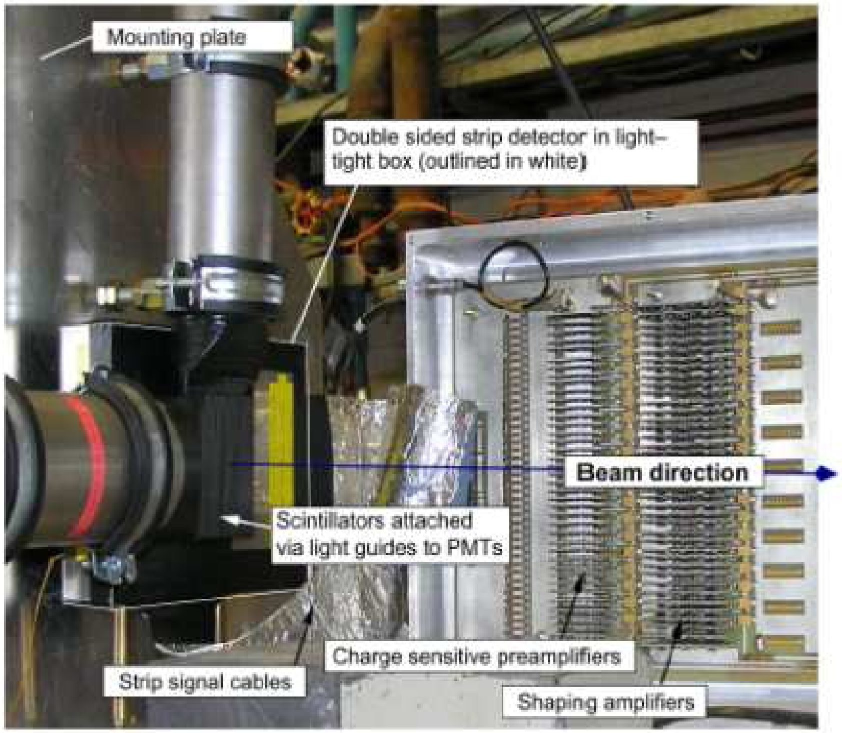
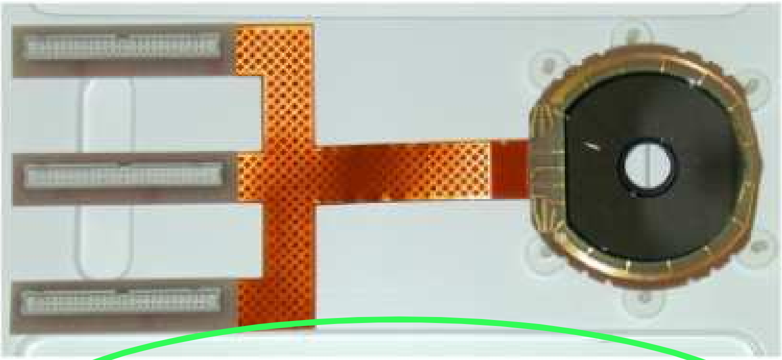
Polarimetry: Prototype Triplet Polarimiter

Ken Livingston
GlueX Upgrade Workshop, May 2012

- Michael Dugger has shown in simulation that a triplet device is feasible
- Between Glasgow and Mainz we have enough bits to prototype and test.



Electronics: Glasgow
Angular distribution of coherent bremsstrahlung, D.Glazier, K. Livingston et al, NIM A664, 2012



Annular double sided strip detector: Mainz/Pavia
Micron S2: 48 rings, 16 Sectors, 1000um
From Daphne detector. P.Pedroni, INFN, Pavia.

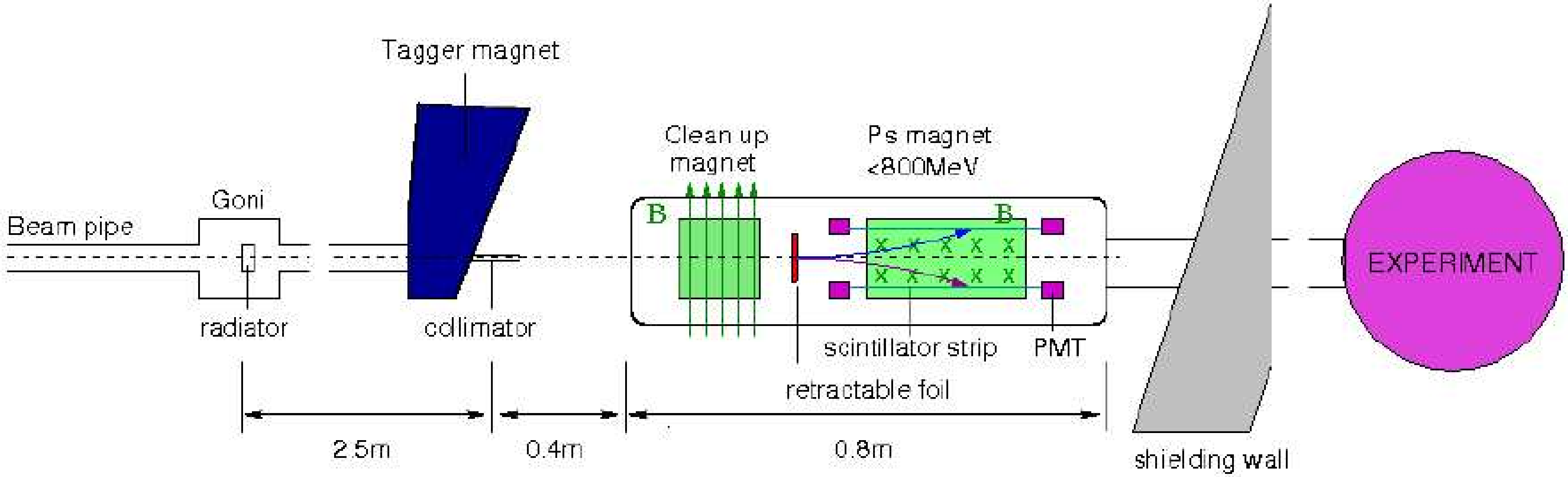
Have annular triplet detector + electronics

Can we develop a prototype and test configuration in Mainz?

Polarimetry: Prototype Triplet Polarimiter

Ken Livingston
GlueX Upgrade Workshop, May 2012

MAINZ, MAMI A2 Hall, Pair spectrometer (*Juergen Ahrens*)
(not to scale)



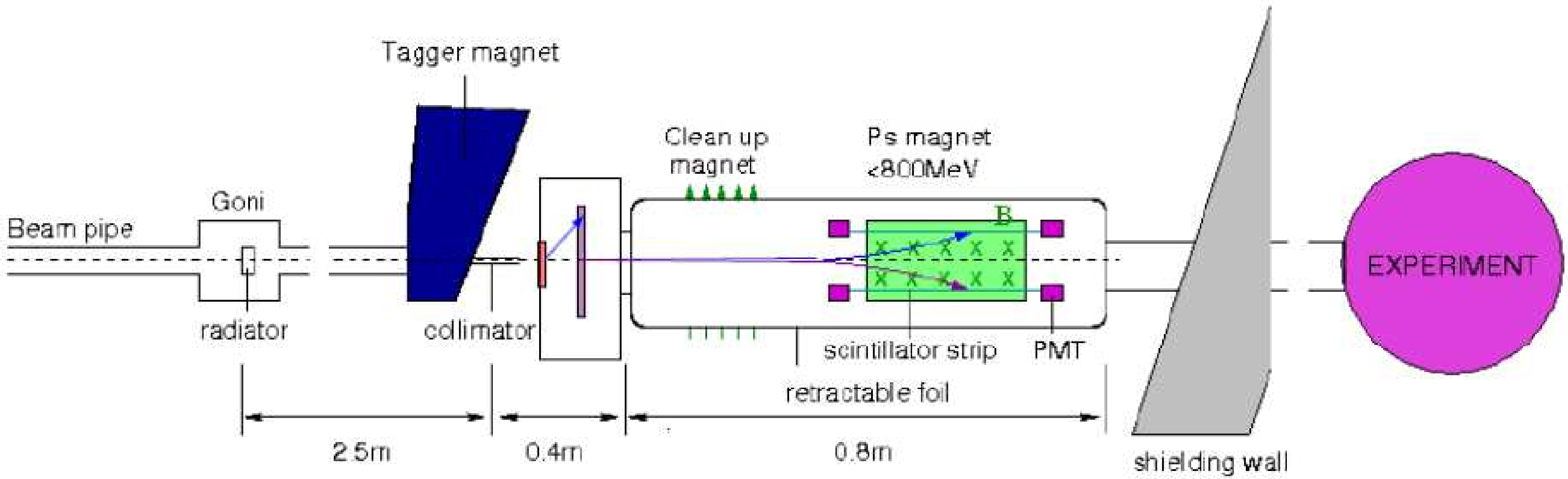
Pair spectrometer already installed and working in Mainz.
No photon energy differentiation – aim was for flux monitoring

How can we use this setup to test the triplet polarimeter.

Polarimetry: Prototype Triplet Polarimiter

Ken Livingston
GlueX Upgrade Workshop, May 2012

MAINZ, MAMI A2 Hall, Pair spectrometer
(not to scale)



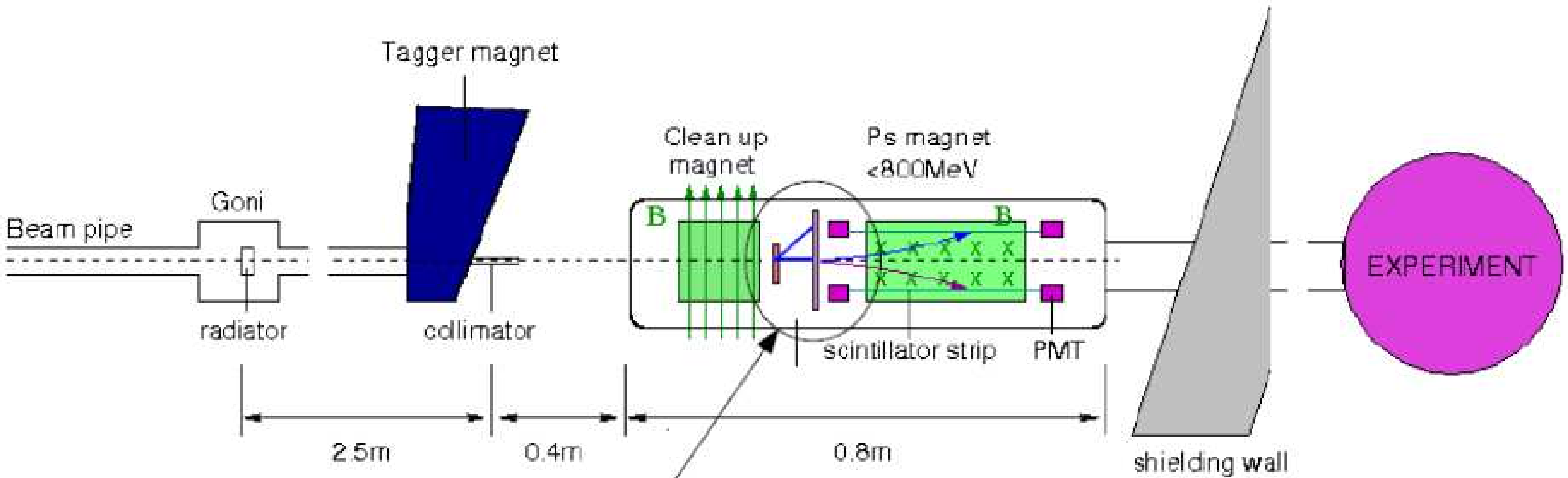
Test setup
Install triplet chamber on front of PS vacuum box.
Remove cleanup magnet and retract PS foil

Issues:
Rate of good triplet events. Background from collimator / air.
Stray magentic fields. Shielding.

Polarimetry: Prototype Triplet Polarimiter

Ken Livingston
GlueX Upgrade Workshop, May 2012

MAINZ, MAMI A2 Hall, Pair spectrometer
(not to scale)

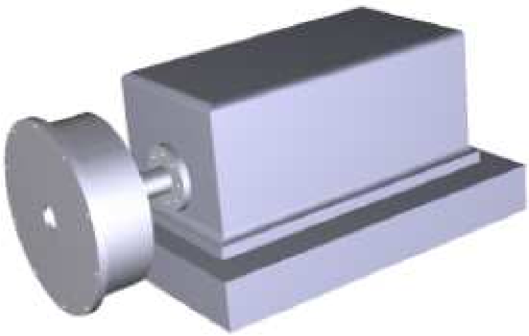


A permanent fixture ?
If test is successful we can make this permanent in Mainz
Ideal position, between cleanup magnet and PS magnet
Issues
Rate of triplet events at normal running rates may be low

Polarimetry: Summary

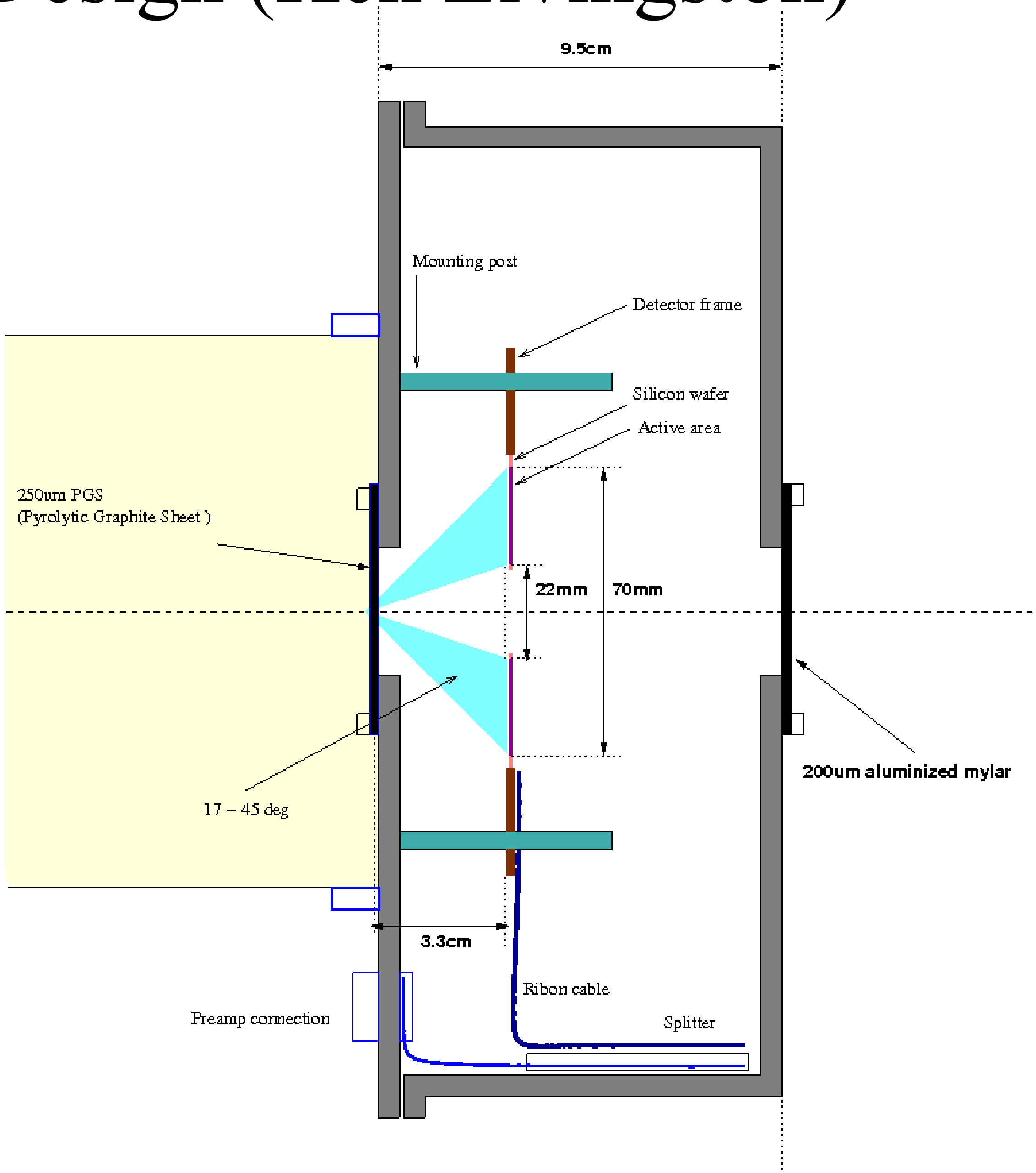
Ken Livingston
GlueX Upgrade Workshop, May 2012

- **Let's not forget the dear old bremsstrahlung calculation**
  - < 5 % with the coherent peak at ~1/3 endpoint energy (Hall B)
- **Triplet polarimeter**
  - Simulations show it is feasible
  - Build and test prototype in Mainz with existing parts.
- **Status of prototype**
  - Detector and electronics in Glasgow, design of chamber underway
  - Lab tests in Glasgow – Summer 2012
  - Beam test in Mainz – Fall 2012
- **Required**
  - Info from Mainz on stray fields.
  - Simulations based on Mainz specs.

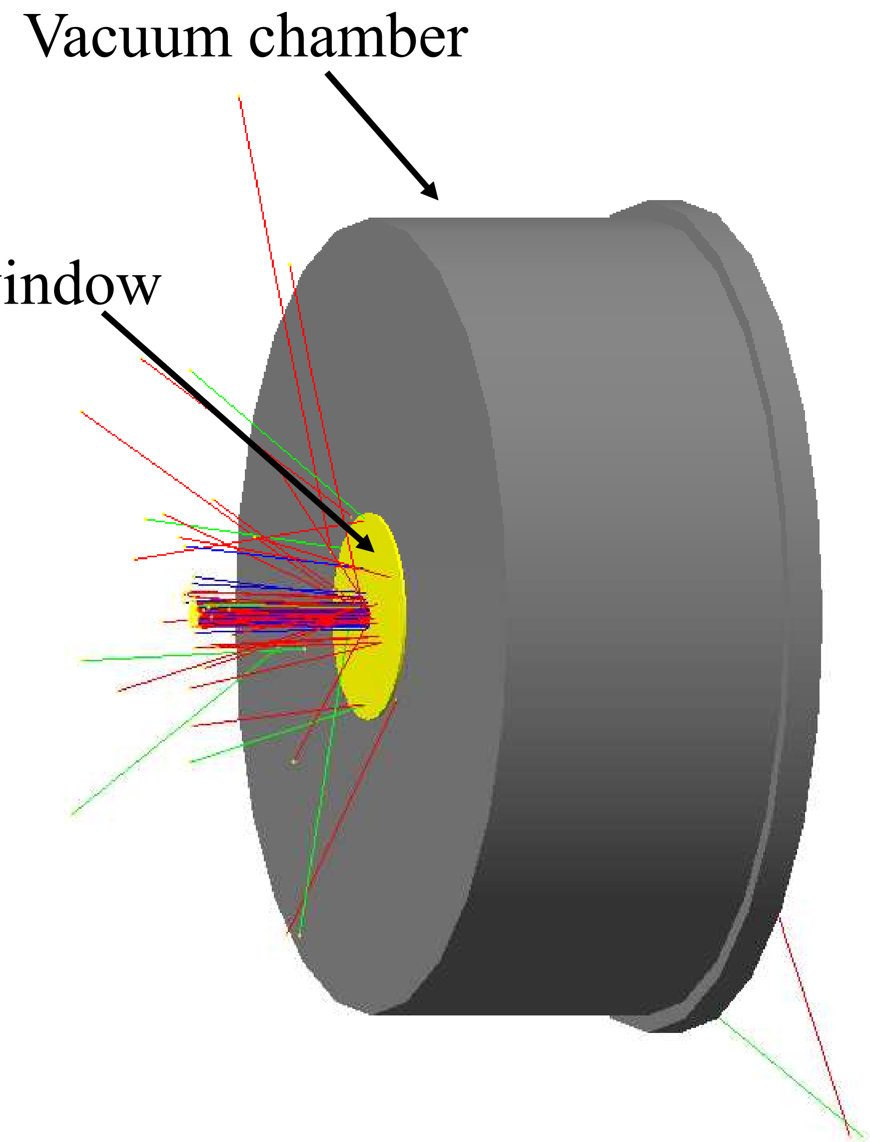


New

Mainz Design (Ken Livingston)



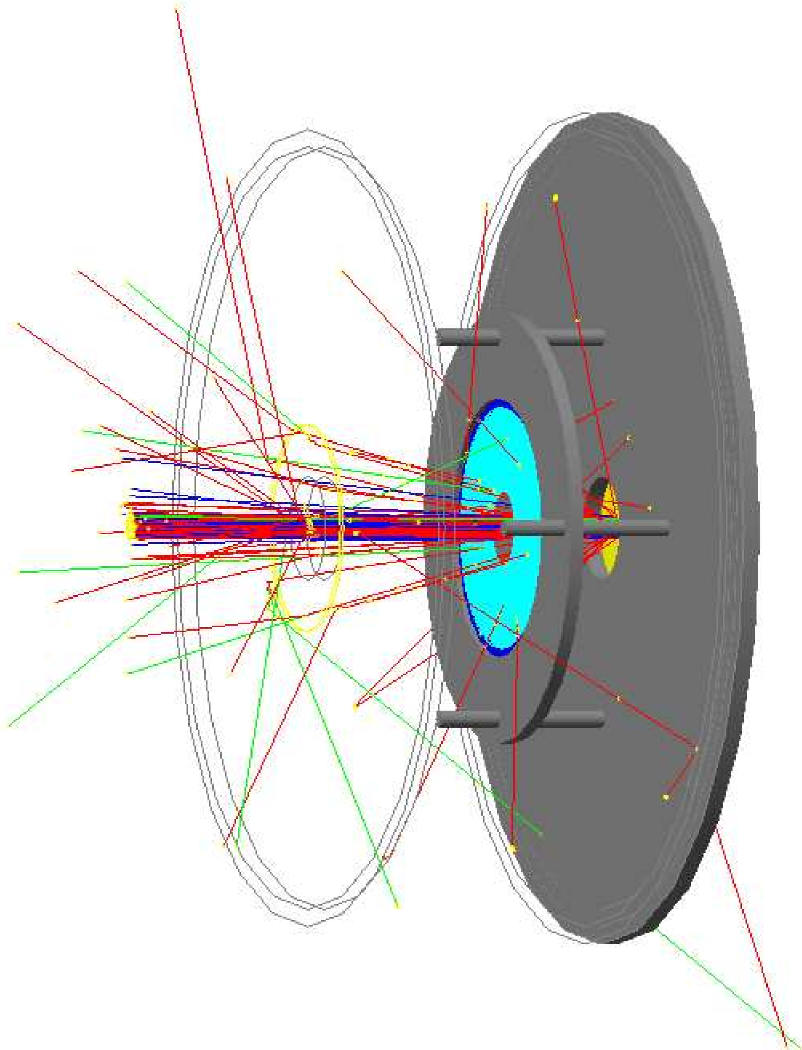
ASU Simulation of Mainz Design



- 200 triplet events thrown

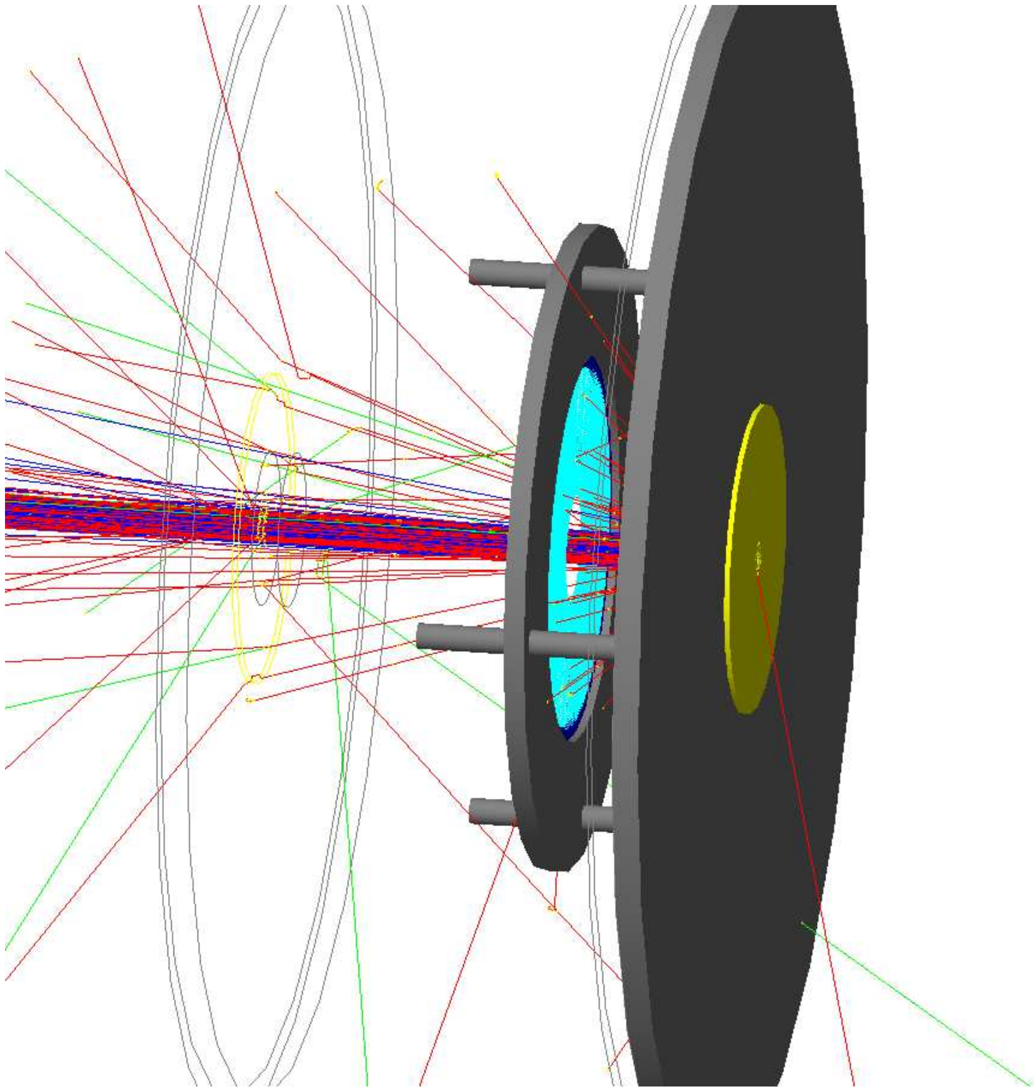
ASU Simulation of Mainz Design

• Set side and downstream parts of chamber to wireframe



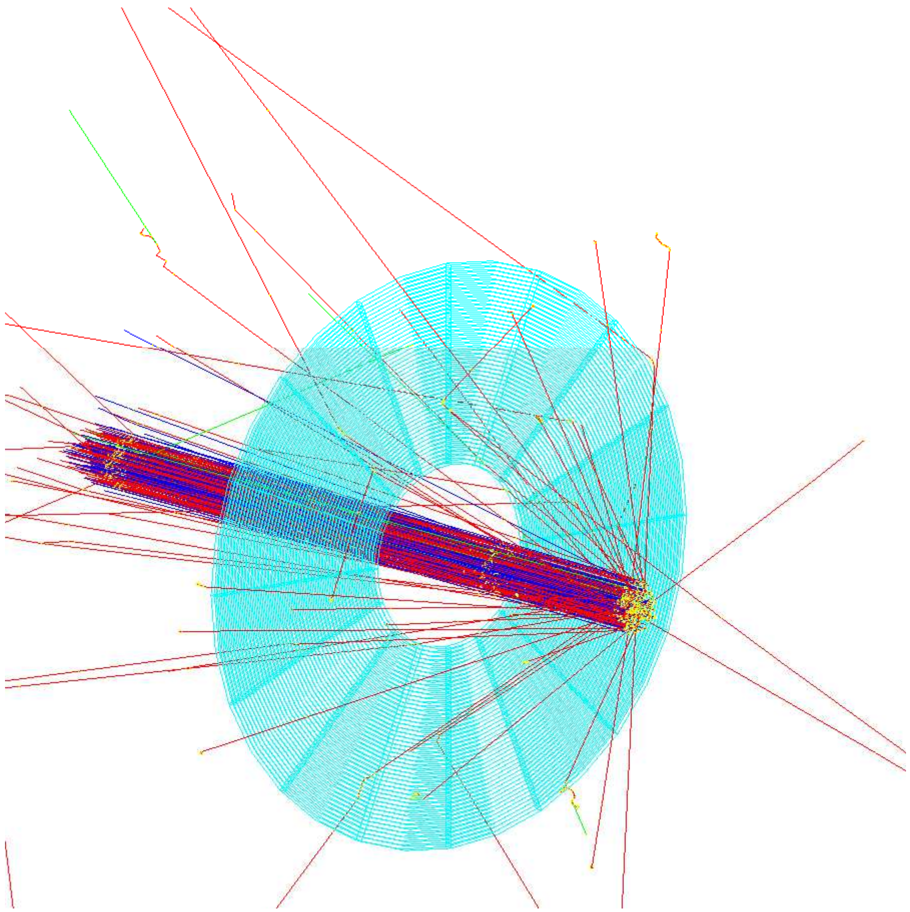
ASU Simulation of Mainz Design

- Rotated and expanded view



ASU Simulation of Mainz Design

• 200 triplet events with chamber and supports set to "invisible"



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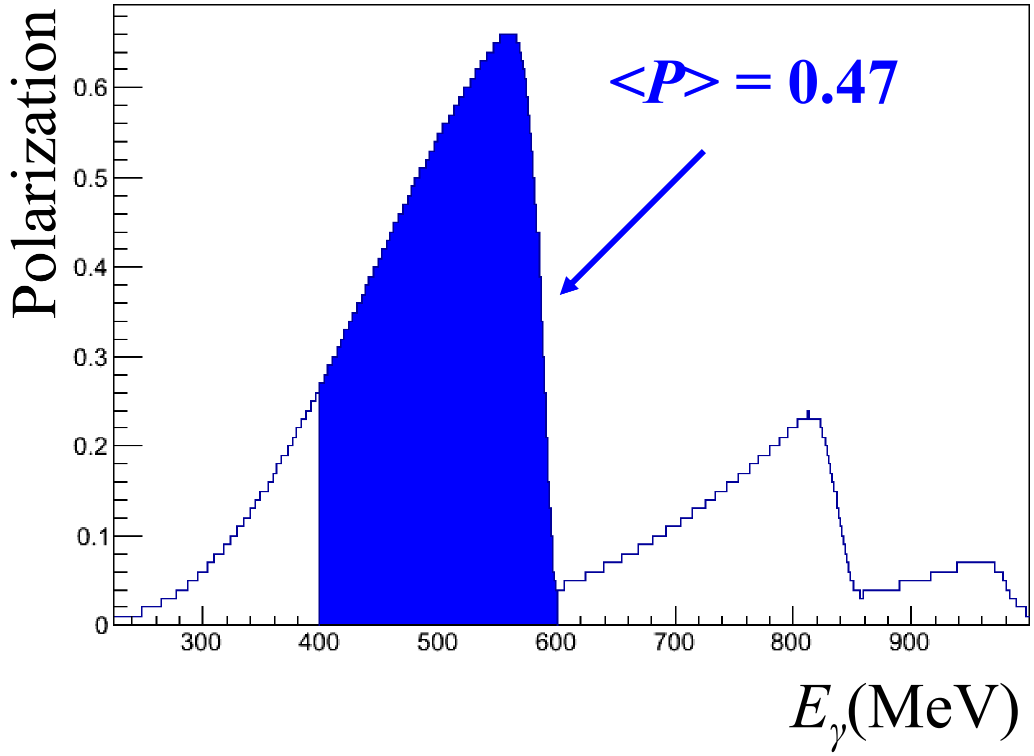
Expected Mainz photon polarization

- Distribution provided by Ken Livingston

- Electron beam energy = 1500 MeV

- Coherent edge = 600 MeV

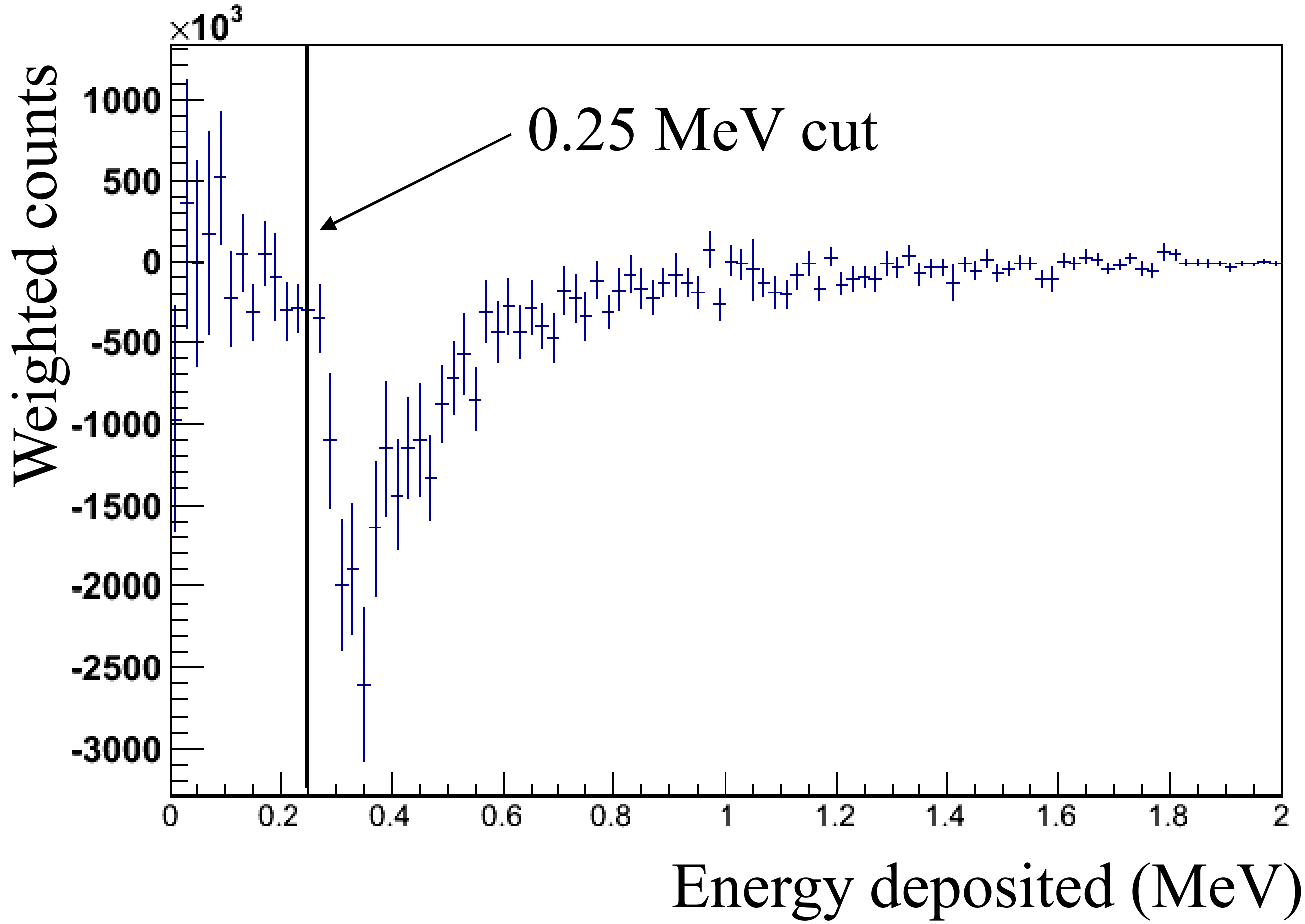
- The rest of the slides will assume a 500 MeV photon beam with Polarization = 0.47



- Should be able to use a much finer energy binning than what is shown on the plot, but just simulating a single energy for now

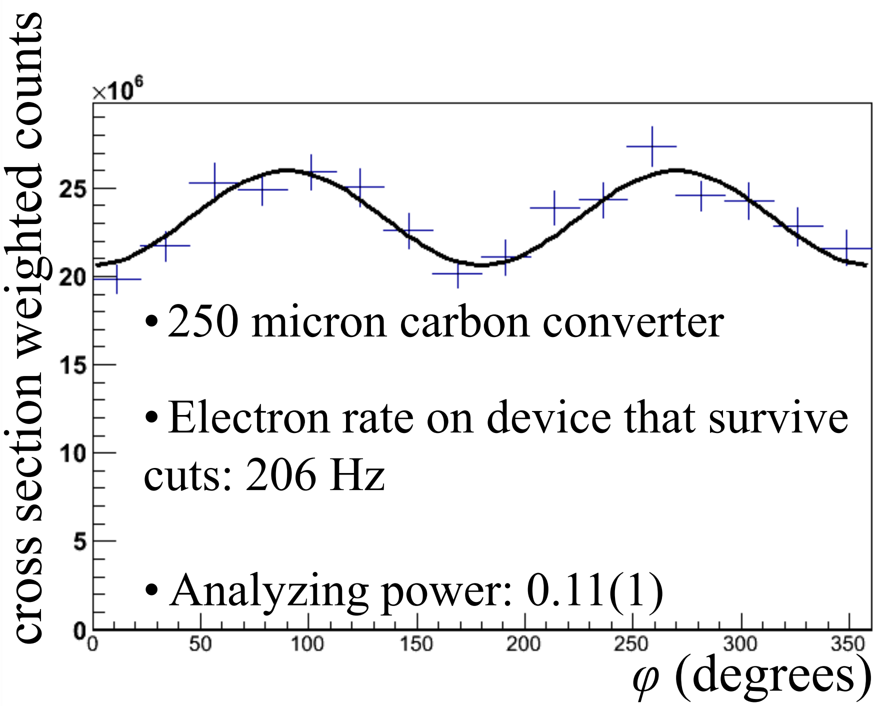
Energy cut

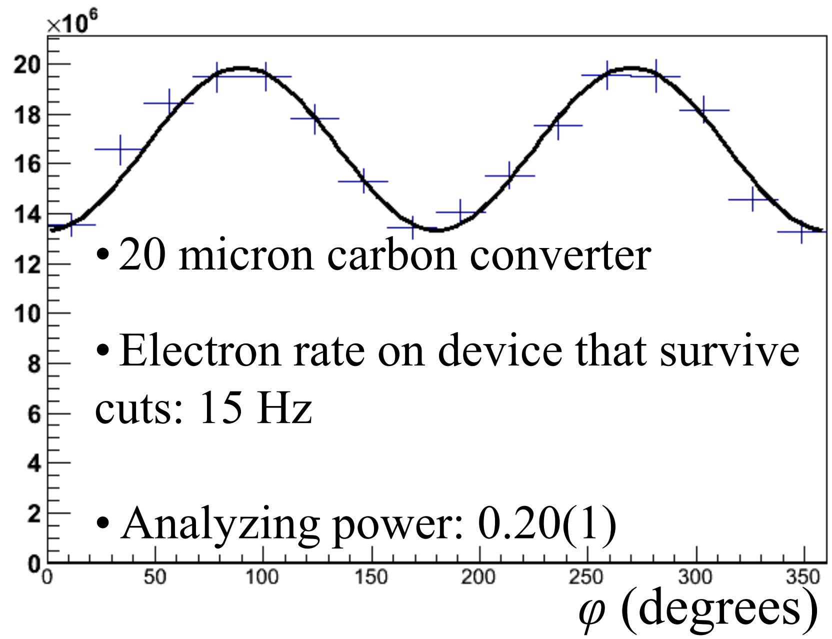
- Events weighted by σ cos(2φ)



Simulation results

- Assumed collimated photon rate (over 200 MeV range) : 4.8×10^7 Hz
- $\Delta E_{pair} < 200$ MeV
- One million events thrown





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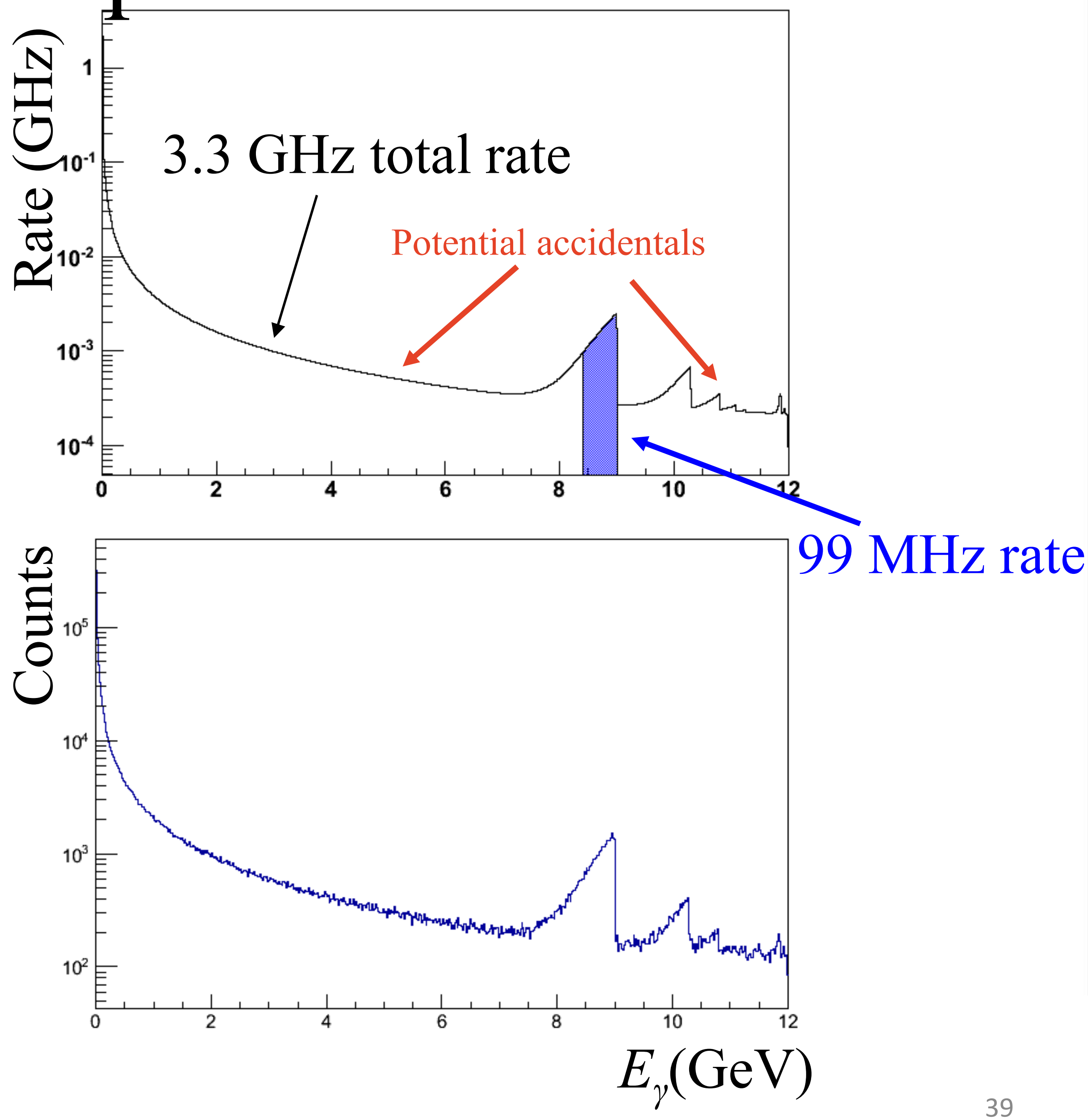
Estimate of accidentals for the triplet polarimeter

Collimated photon distribution

• Used Richard's cobrems_root code to create shape of E_γ distribution (top panel)

• Used shape of E_γ to generate 1 million events (bottom panel) that were fed into the triplet-polarimeter Monte Carlo



Accidental estimate

- For 1 million events thrown (N_T) there were 177 events seen (N_S) on the polarimeter

- Assumed a lithium converter of 10^{-3} radiation lengths

- Total expected photon rate: $R_\gamma = 3.3$ GHz

- Expected total photon rate seen on device:
$R_S = R_\gamma *(N_S/N_T) = 3.3\text{GHz}*(177/1\text{million}) = 584$ kHz

- Expected number of polarimeter hits for a 20 ns window:
$<n_{5ns}> = R_S*20\text{ns} = 0.012$

- Probability of accidental coincidence between pair spectrometer and polarimeter: $P_{acc} = 1 – P_0(<n_{5ns}>) = 1.2$ %

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